More than just postponement: quantifying the contributions of education and unions to the fertility gap by simulating the reproductive life courses of Dutch women

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Abstract

Couples have fewer children than they intend to in Europe, resulting in a gap between intended family size and completed cohort fertility. This is largely because first-pregnancy attempts are postponed to older reproductive ages, due to expansion of higher education and less stable unions, among other things. Postponement of pregnancy to older reproductive ages makes successful pregnancy and birth more difficult due to age-related physiological constraints on fertility, but these constraints are rarely modelled. It is difficult to model how age, education, the timing of, and prevalence of union formation and -dissolution influence the fertility gap with statistical techniques commonly used in fertility research. We therefore constructed a microsimulation model with detailed information on union formation and the reproductive process to measure how much changes in education and union timing and -prevalence contribute to the fertility gap of Dutch women. Our model parameters were based on Generations and Gender Survey I and LISS panel data, complemented by other sources. We found that marriage, separation and re-partnering contributed more to the fertility gap than divorce, due to 70% of women marrying and late divorce. Contrary to expectations, even a substantial increase in the share of highly educated women barely increased the gap. Postponement of first cohabitation due to education was short enough for higher union stability to compensate for most of the difference in timing and prevalence of first cohabitation. The contribution to the gap increased with the length of postponement because of physiological constraints on fertility at higher reproductive ages.

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Introduction

Couples across Europe are having fever children than they intend to, and the gap between *intended family size* and *completed cohort fertility* is sizeable in many European countries, including the Netherlands. Intended family size has tended to average close to 2 children per woman, whereas completed cohort fertility is well below *replacement level* (2.1 children per woman) and declining across Europe, resulting in a fertility gap. The average size of the gap was 0.28 for women born in the 1960s-1970s in 18 EU countries and the US, with the Netherlands being close to the average (Beaujouan and Berghammer, 2019; Testa, 2014). Estimates using tempo-adjusted total fertility suggested a mean gap of 0.34 in the EU 27 in 2006 (Sobotka and Lutz, 2010).

A large share of the fertility gap is likely attributable to postponement of first-pregnancy attempts to increasingly older ages, when physiological constraints reduce the probabilities of pregnancy and live birth (Magnus et al., 2019; Sauer, 2015). Expansion of higher education and recent changes in union formation and -dissolution patterns are considered two important individual-level contributors to this postponement (Andersson et al., 2022; Ní Bhrolcháin and Beaujouan, 2012; Winkler-Dworak et al., 2017). We have chosen to focus on these two in our study. Other possible contributors include perceived and actual economic and employment uncertainty both at the household and national level, household division of labour, and work-life balance, to name a few (Balbo et al., 2013; Beaujouan and Berghammer, 2019).

We identify two mechanisms through which education influences fertility. First, childbirth during enrolment in higher education is very rare, resulting in postponement of attempted first pregnancy until completion of education (Adda et al., 2017; Doepke et al., 2022). Second, there are educational gradients in union formation and -dissolution, which in turn influence fertility. As the vast majority of births occur in cohabiting unions (marriage and cohabitation), postponement of first cohabitation is directly linked to postponement of first birth. Generations and Gender Survey (GGS) and LISS survey data both suggest a positive association between educational attainment and age at first cohabitation for the Dutch cohort studied in this paper. Assuming assortative mating, highly educated women likely have a more difficult time finding a partner to form a family with; due to the increasing gap in higher education attainment between the sexes (Eurostat, 2023; Raley and Sweeney, 2020; UNECE, 2023; van den Berg, 2023; van den Berg and Verbakel, 2022). On the other hand, highly educated women in our data had lower rates of separation and divorce, which Finnish register data for the past two decades supports (Jalovaara and Andersson, 2023). So, more highly educated women cohabit later and somewhat less, but have more stable unions.

Our study uses microsimulation to generate hypothetical reproductive life courses of Dutch women born between 1974 and 1984. We choose this cohort because we need information on the women's intended family size early in their reproductive lives, and their completed fertility; to measure of the gap between the two. This cohort also experienced the considerable changes in union formation and -dissolution trends as well as expansion of higher education over the past few decades. We construct a model with information on the intended family size and educational attainment of the women, as well as detailed information on union formation and -dissolution, and the reproductive process. The model is validated using cohort fertility data from the Human Fertility Database. We quantify the contributions of changes in education, marriage, cohabitation, divorce, and separation on the gap between intended family size and completed cohort fertility. This is done by adjusting the respective parameters in our model, while keeping all the other parameters constant.

Our research question is:

> *How much did union formation and -dissolution as well as educational attainment contribute to the gap between intended family size and completed fertility for Dutch women born between 1974 and 1984?*

While most quantitative fertility studies include information on education and union status, few consider physiological constraints on fertility, even though these constraints are the most proximate determinants of the success of a pregnancy and birth. Instead, age is usually included as a capture-it-all independent variable, and *perceived control* (intentions, values, norms etc.) over fertility serves as a proxy for *actual control* over fertility (Ajzen and Klobas, 2013). This problematic not only because it contradicts the evidence of a gap between fertility intentions and completed fertility, it also ignores that age-related physiological constraints on fertility mediate the effects of more distal determinants of fertility like education and union status. Failing to control for these mediating constraints may therefore bias results and undermine claims of causality.

We address these shortcomings with our microsimulation model. First, we explicitly model the age-related physiological part of the reproductive process (fecundability, intrauterine mortality). Deliberate control over fertility (contraception, induced abortion) is also modelled. Second, we are able to model the interdependence between the union formation- and reproductive processes, control for education, and account for time-dependence; due to the iterative nature of our simulation approach. Modelling such complex sets of transitions is considerably more difficult using other methods for generating hypothetical life courses, like multistate life tables (Thomson et al., 2012). As our simulation model is built up from the individual components (cohabitation, separation, marriage, divorce, educational attainment, etc.) of the fertility process, so we able to estimate and measure the contribution of each of these components to the gap between intended family size and completed fertility. This is difficult in a regression setting, because of the independence assumption between covariates and issues of autocorrelation when dealing with processes over time.

Some microsimulation studies have already modelled the physiological constraints on human reproduction, but they have not included important socioeconomic variables like education, and have had very simple assumptions about union formation (Ciganda and Todd, 2021; Eijkemans et al., 2014; Habbema et al., 2015; Leridon, 2004; Leridon and Shapiro, 2017). Other more theory-driven microsimulation studies have modelled union dynamics in more detail, but have not considered physiological constraints on fertility (Thomson et al., 2019, 2012; Winkler-Dworak et al., 2021, 2017). Our study breaches this gap by including socioeconomic variables (education to begin with), having fairly realistic union dynamics, as well as modelling the reproductive process in detail.

Data

The main sources of data were Generations and Gender Survey I wave 1 (Netherlands) and LISS panel waves 1-15 (Family & Household, Work & Schooling). For a description of the data see **Table 1**.

Methodology

Conceptual framework

The conceptual framework of this paper, which summarises the theoretical and empirical discussion in the literature review is depicted below. The only relationship that is not modelled in the simulation is the negative relationship between parity and re-partnership, as was discussed in the literature review. In addition to the negative relationships from educational attainment to separation and divorce, the data suggests a negative relationship between educational attainment and cohabitation (fewer highly educated women ever cohabit), and an inverse u-shaped relationship between educational attainment and marriage (the share of cohabitations resulting in marriage). This is shown in **Table 2**.

The simulation models

Our simulation is a Monte Carlo microsimulation, which means that randomly drawn numbers are compared to specific transition conditions. If the conditions of a transition between two states is met, the event occurs, if not, the woman stays in her present state. Our simulation builds on modelling work by Henry Leridon (1997, 2004, 2008, 2017), but our model is quite different and extends on Leridon's latest model[3] (Leridon, 1977, 2004, 2008; Leridon and Shapiro, 2017). We use R to construct our simulation models. The simulations are `while` loops containing multiple `if…else` statements.

We split the simulation into two parts: the simulation of the union trajectories and the simulation of the reproductive process. As the former depends on the latter, this is the order in which the simulations are run. Our simulation models are run for *an individual woman*. So, as we sample 100,000 women the simulations run 100,000 times each. The models iterate monthly to follow the menstrual cycle, which is estimated to be 29.3 days on average based on recent Swedish, UK, and US data (Bull *et al.*, 2019). They run from age 15 to age 55, covering the entire reproductive life course of a woman. How the respective simulation models operate are depicted in **Figures 2 and 3**.

[3] Leridon wrote his model in Pascal, whereas we wrote our model in R. The way the simulations work are also quite different and we include several additional parameters to our model.

Results

Based on our simulation results, the fertility gap was mainly a result of underachievement of intended family size among women who intended to have two or three children (**Figure 4**). Education barely contributed to the fertility gap, because later and less partnering among highly educated women was compensated for by more stable unions (see tables 2-4). Postponement due to enrolment in education also had a negligible contribution, since the mean age at first cohabitation among highly educated women was several years higher than the expected age at graduation from higher education. Moderate changes in marriage, separation, and re-partnering all had small contributions to the fertility gap. Divorce essentially had no contribution to the gap, since only around 70% of women ever married, and the mean age at first divorce was quite high. The contribution of postponement of first cohabitation increased with the duration of postponement due to physiological constraints on fertility at older reproductive ages. A reduction in the share of women who ever partnered contributed substantially to the fertility gap.

Appendix

Table 1: Description of the data (continues on next page)

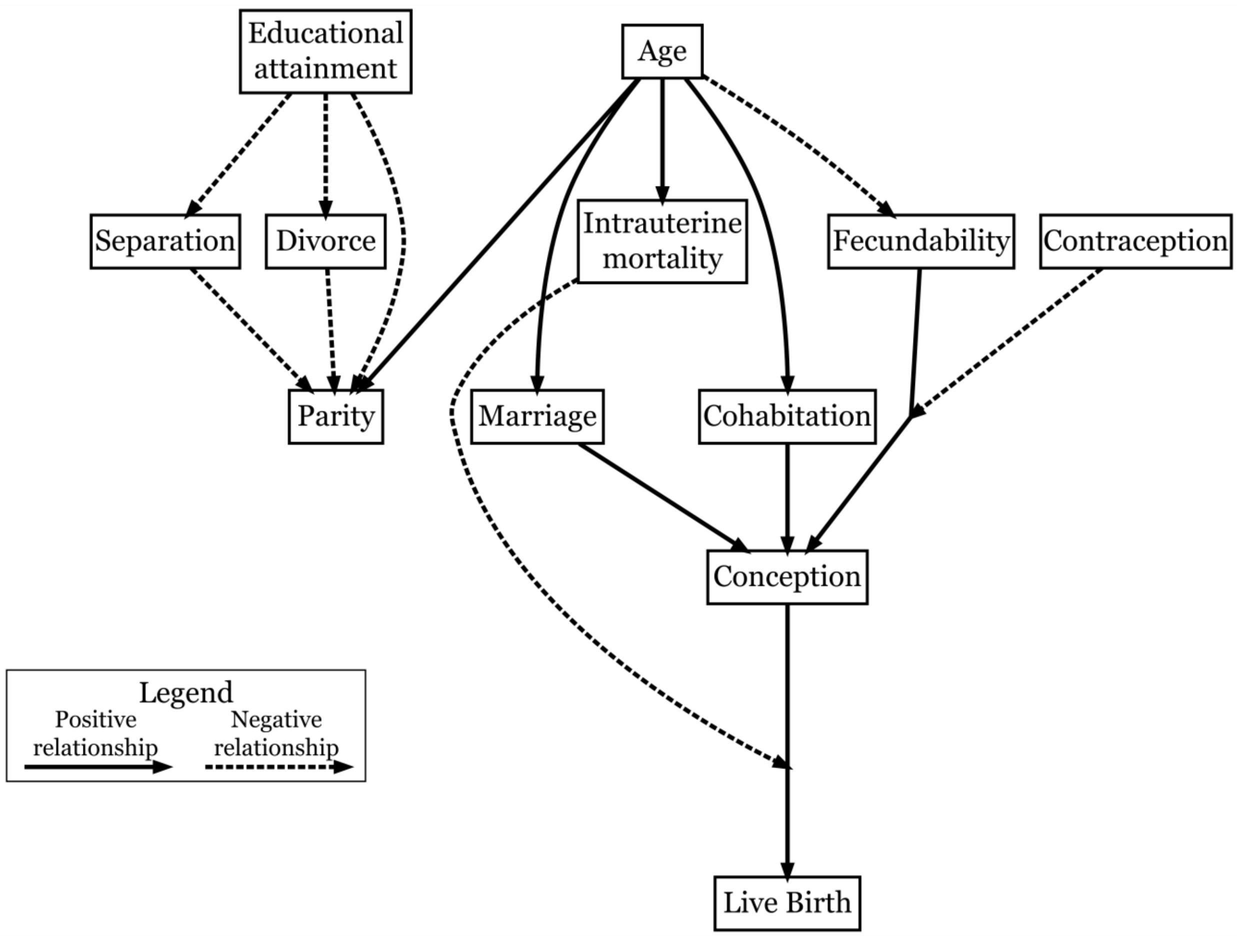
Parameter	Sample size	Processing/information	Format
Fecundability	-	Beta distribution (a = 3, b = 9, mean ≈ 0.25), 12.5 years of linear decline before age at sterility (Leridon 2004, 2017)	Sampling from PDF
Intrauterine mortality	-	Fitted third degree polynomial distribution to values estimated by Leridon (1977), Month of miscarriage distribution based on clinical data[1]	Same intrauterine mortality CDF for all women, sampling from distribution month of miscarriage distribution
Non-susceptible period	-	Live birth: truncated normal distribution (mean = 4, lower = 0), miscarriage & abortion[2]: 1 month	Live birth: sampling from distribution, miscarriage & abortion: same for all women
Age at permanent sterility	-	Cubic spline interpolation between yearly data points by Leridon (2017), sampling from distribution	Sampling from distribution
Intended spacing	-	9 months of pregnancy + 5 months[3] waiting subtracted from the difference between the mean age at first cohabitation and the mean age at first birth, and HFD birth interval differences	Same distribution for all women
Spacing contraception	-	90% efficacy ages 15-25, 70% ages 26-55[4]	Same for all women
Stopping contraception	-	98.3% efficacy based on Leridon (2017)	Same for all women

[1](Dugas and Slane, 2023; Wilcox et al., 1988), [2](Leridon, 1977, p. 83; Theurich et al., 2019),[3](Donnet et al., 1990; Schreiber et al., 2011), [4](CBS, 2014)

Parameter	Sample size	Processing/information	Format
First cohabitation (and cohabitation)	ISCED 0-2: 178, ISCED 3-4: 472, ISCED 5-8: 659	Gumbel distribution, cohort share who ever cohabit 95% based on 1954-1964 GGS cohort, education specific shares calculated with equation systems from the ratios between the shares of the same cohort summing up to the cohort share, share who stay cohabited after first cohabitation 10%[1]	RNG compared with CDF value corresponding to the iteration/month
Cohabitation to marriage	ISCED 0-2: 313, ISCED 3-4: 803, ISCED 5-8: 709	Exponential distribution, cohort share who marry of 58.0% based on CBS reports[1], 70% share who ever married based on CBS estimates[2], education specific shares estimated the same way as first cohabitation but based on the LISS 1964-1984[3] cohort (no information on the year of marriage in GGS)	RNG compared with CDF value corresponding to the iteration/month
Separation	710	Exponential distribution, cohort share who separate of 31.2% based on CBS report[4], education specific shares estimated the same way as first cohabitation	RNG compared with CDF value corresponding to the iteration/month
Re-partnering	250	Gumbel distribution, Re-partnering set at 75%, based on Finnish 1969-1971 birth cohort (76.2%)[5]	RNG compared with CDF value corresponding to the iteration/month
Divorce	488	Exponential distribution, cohort share who divorce of 27.6% based on CBS report[6] (separate + marry*divorce = 48%)[1], education specific shares estimated the same way as first cohabitation	RNG compared with CDF value corresponding to the iteration/month
Abortion	-	90% probability, abortion ratio and month of pregnancy in which abortion occurred based on official statistics[7]	Same probability for all women, month of pregnancy sampled from distribution
Education	3,835	Educational structure from LISS and GGS, duration of enrolment based on expected year of graduation	Educational attainment sampled from distribution

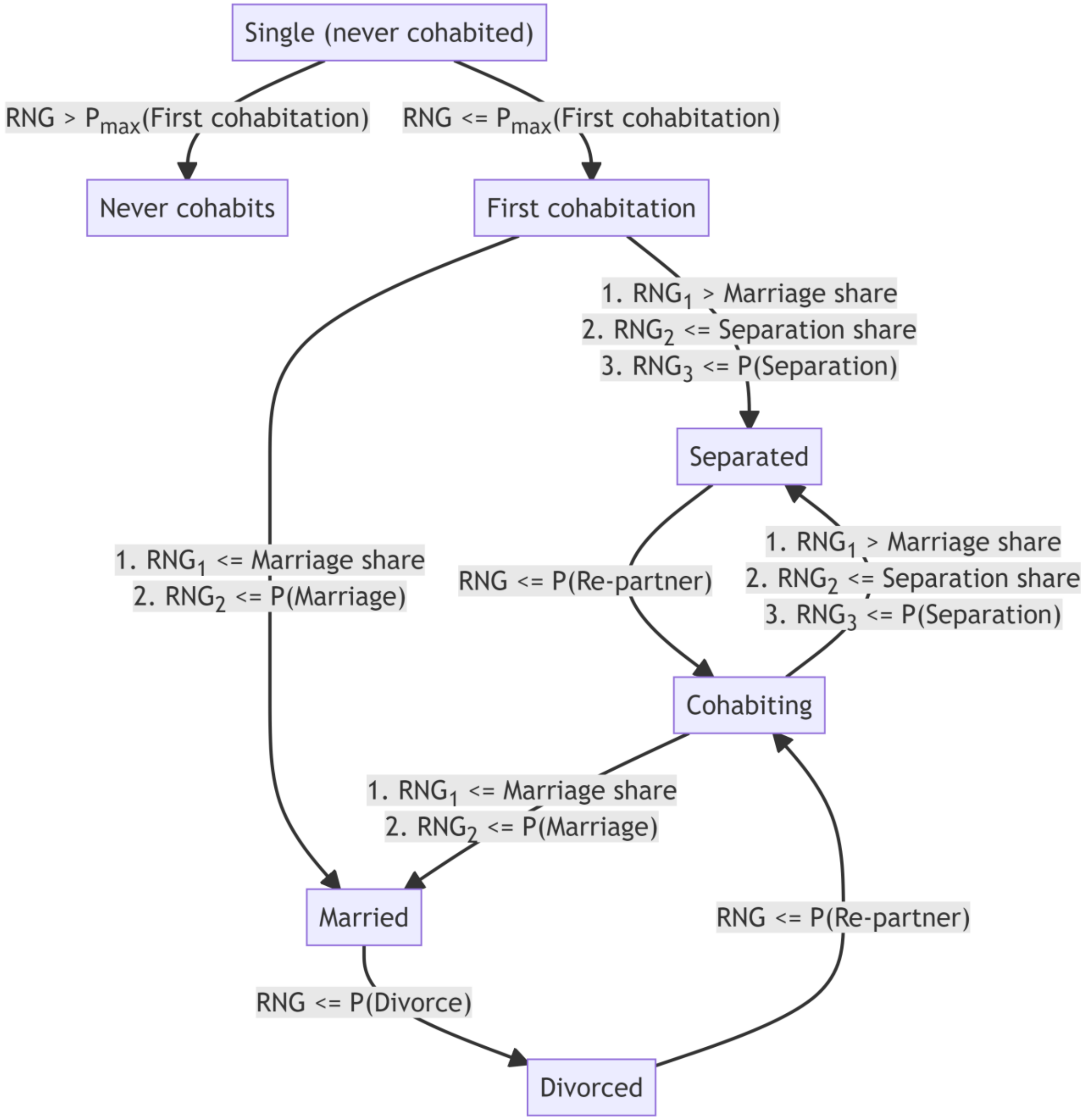
[1](CBS, 2019)**, [2]**(Stoeldrajer et al., 2021, sec. 3)**, [3]**Cohort range expanded by 10 years for a larger, more representative sample, [4](Kooiman et al., 2021), [5]Table 1: Ever repartnered / (Never repartnered & separated + Ever repartnered). Data is both sexes combined (Andersson et al., 2022), [6](Kooiman, 2022), [7](MVWS, 2021, 2017)

Figure 1: Conceptual framework



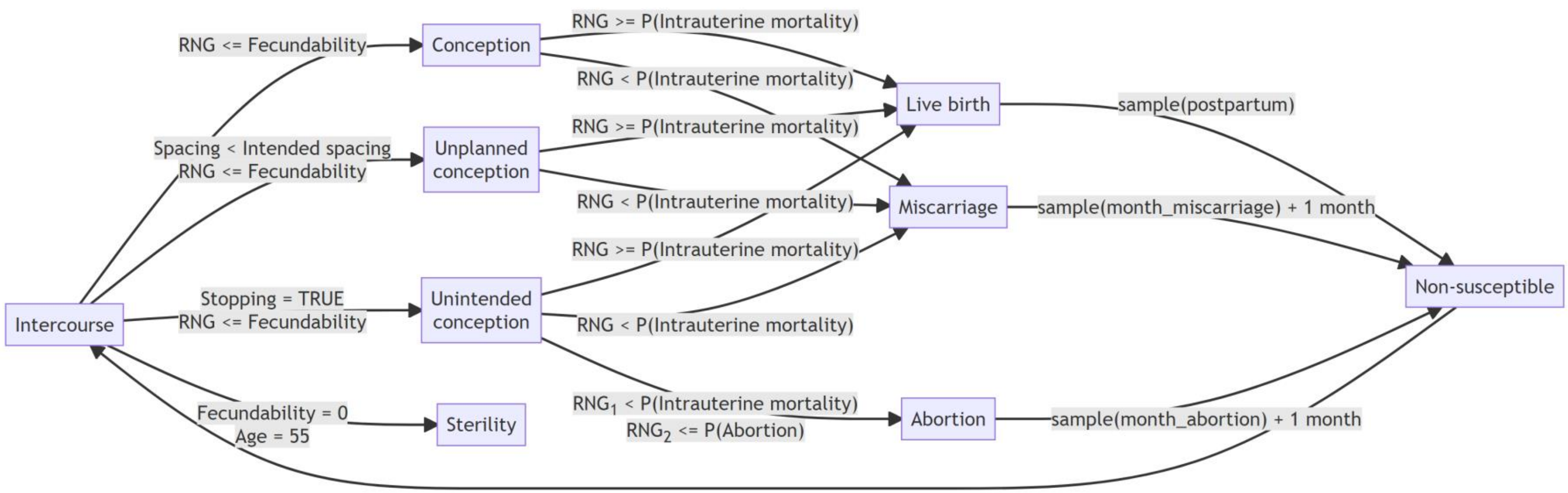
Notes: Framework based on literature review. The negative relationship between parity and re-partnership is not modelled (see discussion in literature review).

Figure 2: Union formation simulation



Notes: RNG refers to a (pseudo) randomly generated number between 0 and 1, which is compared to a cumulative distribution function. The month in which the randomly generated number meets the specified transition condition(s) the event occurs. If the transition conditions are not met, the woman remains in her current state. P_{max} refers to the maximum value of the cumulative distribution function, which in this case ranges from 0.939 (ISCED 5-8) to 0.999 (ISCED 1-2) between the different educational groups.

Figure 3: Simulation of the reproductive process (while cohabiting or married)



Notes: RNG refers to a (pseudo) randomly generated number between 0 and 1. Stopping is when the woman has reached her intended family size, spacing is the period during which the woman is not yet trying to get pregnant. Sterility is an absorbing state, and ends the simulation. Abortion here refers to (medically) induced abortion, whereas miscarriage is sometimes referred to as spontaneous (unintended) abortion. The third steps (arrows) from live birth, miscarriage, and abortion to non-susceptible denote the time spent in the state of non-susceptibility. 'sample' refers to random sampling from the corresponding distributions.

Table 2: Simulation results versus reference data (100k sample)

Indicator	Demographic data	Simulation results (1974-1984 cohort)
Mean age at first marriage (CBS, estimated)	30.1	29.22
Mean age at first cohabitation (GGS, LISS)	24.5	24.30
Mean age at first separation (GGS, LISS)	28.5	28.15
Mean age at first divorce (GGS, LISS)	37.6	38.07
Mean age at first repartnering	NA	33.32
Mean number of partners (GGS 1954-1964 cohort)	1.20	1.432
Percent ever cohabited (GGS, estimated)	95.0	95.05
Percent ever married (CBS, estimate)	70.0	72.20
Percent cohabited & never separated or married (CBS)	10.0	9.439
Percent marriage (CBS, estimated)	58.0	57.08
Percent divorce	27.6	24.97
Percent separation	31.2	31.67
Percent repartnering	75.0	73.29
Mean age at first birth (approx, 1979)	29.2	28.12
Mean age second birth (approx, 1979)	31.6	30.42
Mean age third birth (approx, 1979)	33.1	32.17
Mean age fourth birth (approx, 1979)	34.5	33.60
Completed cohort fertility (approx, 1979)	1.80	1.691
Fertility gap (intended - completed)	0.227	0.3325
0 children (1969 cohort, %)	17.6	24.47
1 child (1969 cohort, %)	18.5	11.11
2 children (1969 cohort, %)	42.7	42.13
3 children (1969 cohort, %)	15.6	16.78
4+ children (1969 cohort, %)	5.60	5.518
Miscarriages per live birth	NA	0.2073
Percent unplanned births	30.0	32.77
Percent unintended births (less than)	5.00	1.709
Abortion ratio 2000-2020 (abortions per 1,000 live births)	154.	153.2

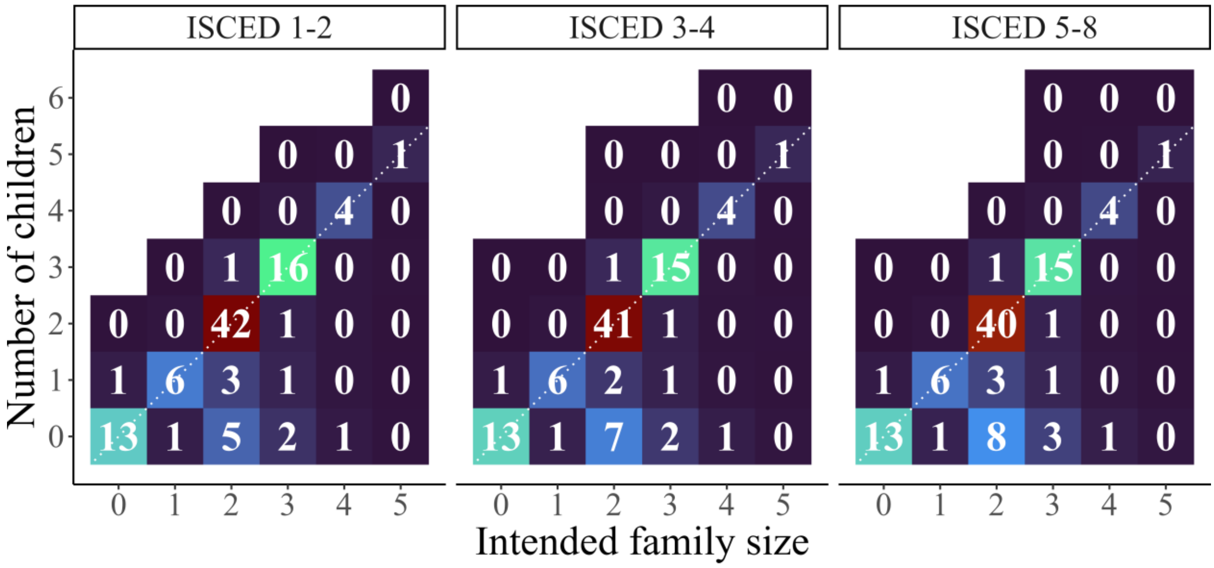
Table 3: Simulated averages by education (100k sample)

Educational level	ISCED 1-2	ISCED 3-4	ISCED 5-8
Mean age at first marriage	27.55	28.41	30.46
Mean age at first cohabitation	22.35	23.62	25.48
Mean age at first separation	26.33	27.56	29.41
Mean age at first divorce	36.55	37.48	39.26
Mean age at first re-partnering	31.12	32.99	34.56
Mean number of partners	1.72	1.40	1.37
Percent ever cohabited	99.87	94.64	93.94
Percent ever married	75.71	73.41	70.15
Percent marriage (cohabitation-marriage)	51.34	59.63	57.08
Percent divorce	30.17	24.71	23.43
Percent separation	41.91	29.50	29.64
Percent re-partnering	73.42	73.51	73.02
Mean age at first birth	26.45	27.50	29.18
Mean age at second birth	28.89	29.86	31.39
Mean age at third birth	30.72	31.67	33.08
Mean age at fourth birth	32.08	33.19	34.50
Completed Cohort Fertility	1.77	1.71	1.65
Fertility gap	0.25	0.31	0.38
Percent 0 children	21.14	24.21	25.69
Percent 1 child	11.80	10.23	11.63
Percent 2 children	43.27	42.88	41.16
Percent 3 children	17.92	16.88	16.34
Percent 4+ children	5.88	5.80	5.17
Miscarriages per live birth	0.19	0.21	0.21
Percent unplanned births	32.44	31.84	33.67
Percent unintended births	1.81	1.83	1.57
Abortion ratio (abortions per 1,000 live births)	171.28	162.75	139.14

Table 4: Contributions of changes in individual parameters to the fertility gap

Parameters	Adjustment	Contribution to fertility gap
Share of highly educated	Increase by 10%-points*	0.013
Share of highly educated	25-34 year-olds in 2022*	0.010
Share who marry	Decrease by 5%-points	0.023
Share who separate	Increase by 5%-points	0.019
Share who divorce	Increase by 5%-points	0.003
Share who re-partner	Decrease by 5%-points	0.027
Age at first cohabitation	Increase mean by 1 year	0.029
Age at first cohabitation	Increase mean by 3 years	0.061
Age at first cohabitation	Increase mean by 5 years	0.181
Share that ever cohabit	Decrease by 5%-points	0.092

Figure 4: Distribution (%) of women by intended family size and completed fertility.



Note: Most women realised their fertility intentions (diagonal line), underachievement (below diagonal line) was much more common than overachievement (above diagonal line). The fertility gap increased somewhat with education.

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